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Review Paper of Performance Analysis for Random Access Channel in Wireless Network with MAC Protocol

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Abstract

IEEE 802.11 is a well-known standard for wireless local area networks for both infrastructure Based and Ad-hoc networks. In our research we will work on the MAC layer in wireless network. In these work we will study and analyze the theoretical and mathematical model of Random Access channel in wireless network. Wireless Network Aloha is feasibly the simplest and most-studied medium access control protocol in existence. Earlier study on Aloha using a slotted Aloha, Pure Aloha and OFDMA aloha have shown that the usage trend analysis very much depends on the performance of the multiple channel schemes that divided frequency and time slots. But this algorithm has some disadvantage: It may not increase the throughput performance of a MAC scheme [3], [4]. The first drawback does not only concern pure aloha, but all other algorithms. In this work, we will analyze the performance of the medium access control (MAC) mechanism using IEEE 802.11MAC protocol. IEEE 802.11 is a set of medium access control and physical layer (PHY) specification for implementing wireless local area network (WLAN) computer communication in the frequency bands.

Keywords

ALOHA, MAC (Medium Access Channel), OFDMA, 802.11 protocol, Wireless LAN, Multi-access Channel or Random access Channel and CSMA (carrier sense multiple access.

1. Introduction

In wireless communication network, Medium Access Control (MAC) schemes are used to control the access of active nodes to a shared channel.

Wireless ad hoc network face challenges that are not present in wired networks. In wired networks, transmission errors typically occur at a low rate and interference among different communication flows is minimal. Collision detection is usually fast and easy in wired networks. Wireless communication, however, requires a shared transmission medium that is highly error-prone. Hence, in wireless communication, there is a much higher chance for collisions to occur.

It is also more difficult to detect a collision in a wireless network. Often the lack of a wired network, a wireless requires a different and more complicated medium access control layer. Our work focuses on the issues on MAC layer for wireless networks.

The channel access control mechanisms provided by the MAC layer are also known as a multiple access protocol. This makes it possible for several station connected to the same physical medium to share it. Examples of shared physical media are bus networks, ring networks, hub networks, wireless networks and half-duplex point-to-point links. The multiple access protocol may detect or avoid data packet collisions if a packet mode contention based channel access method is used.

MAC Scheme covers three functional areas: reliable data delivery, access control, and security. The MAC layer is responsible for the channel access procedures, i.e. the region behind using a reliable MAC protocol, for increasing throughput of random access channel in wireless network. Extensions of WLAN operating in ad hoc mode are multi-hop ad hoc networks. They are typically deployed in large areas. In these networks, some devices might not be able to communicate directly to each other because of their limited radio range. In such cases, intermediary devices act as relays. In other words, the communication goes through multiple hops before reaching its final destination.

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Multi-hop ad hoc networks do not require any fixed infrastructure, consequently they are easy to deploy. Also, they offer a potential throughput gain. These characteristics make multi-hop ad hoc networks a promising technology. Because of their decentralized nature, multi-hop ad hoc networks offer additional challenges that were not necessarily envisioned during the initial design of current Medium Access Control (MAC) protocols. The MAC protocol is run locally by each network device. Its role is to regulate the access of the devices to a shared resource, the communication channel. In our work we will analyze the fundamental access method of IEEE 802.11 MAC is known as Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA). In CSMA/CA a device wishing to transmit first senses the channel to detect other active devices. If no activity is detected on the channel, the device transmits. Otherwise, its transmission is deferred for a random backoff time. The device uses a timer to count down this waiting time. The value of this timer is decremented only when the device does not detect any activity on the channel. This random backoff is used to reduce the collision probability when the channel becomes idle after a long period of activity. It avoids that all the devices that were waiting to transmit do so at the same time.

In single-hop networks, a device can accurately detect the activity of all other devices and thus appropriately defer its transmissions. This means that only one successful transmission can occur at any given time. In multi-hop ad hoc networks, a device cannot detect the activity of all the other devices. This gives rise to the well-known hidden node problem. A node (or device) is hidden (from a transmitting node) if it cannot detect its transmission but can create a collision at the intended receiver. Yet, in multi-hop networks, it is typically possible and desirable to have several non-colliding transmissions at the same time [19].

A good MAC protocol should schedule a large number of concurrent successful transmissions, but it should also guarantee an equal access to the communication channel to each network node. In other words, a good MAC protocol should provide a high spatial reuse and a fair channel access. These two properties are very hard to achieve in practice.

The standard IEEE 802.11 protocol uses 'virtual carrier sensing'. DCF has two operating modes: the basic channel access mode and the RTS/CTS (Request-to-Send/Clear-To-Send) mode. The RTS/CTS mechanism work as follows. A source node that wants to transmit a frame reserves the channel by exchanging RTS/CTS messages with the target destination node. When a node wants to send packets, it first sends a short RTS request to the receiver node. If the channel is available for use, the receiver replies by sending a short CTS response, which allows the frame, broadcast to start. If the channel is busy, no CTS is sent, and the data frame transmission to begin. If the channel is busy, no CTS are sent, and the data frame broadcast is delayed, thus avoid a collision. The RTS can be retransmitted, if needed, to elicit a CTS response when the channel becomes available. The RTS and CTS packets include the expected time duration for which the channel will be in use for data transmission. Other nodes that overhear these packets must defer their transmission for the duration specified in the RTS/CTS packets. For this reason, each node maintains a variable called the Network Allocation Vector (NAV) effectively reserves the spatial area around the sender and receiver for frame transmission.

An MCMAC protocol extends the IEEE 802.11 MAC to use manifold physical-layer channels [3]. With more than one channel, throughput gains are achievable by allowing multiple transmissions to occur at the same time. Because these immediate transmissions take place on different wireless channels, frame collisions are reduced. In an MCMAC protocol, two steps are needed previous to data transmission. First, a channel cooperation procedure must conclude which channel is to be used for a transmission between two nodes. Second, a channel reservation procedure must notify other nodes regarding how long the preferred channel is reserved for this transmission phase.

The Bi-MCMAC protocol has been proposed as an extension of the IEEE 802.11 MAC protocol. This protocol improves the TCP performance in multi-hop wireless ad hoc networks and also reduces the link-layer contention using two key ideas [3]. Wireless communication between users is becoming more popular than ever before. Due to recent technology advances in wireless data communication devices, such as wireless LANs. This has lead to lower prices and higher data rates, which are the two main reasons why mobile computing continues to enjoy rapid growth [3].

2. Literature Survey

This section provides some discussion about several MAC Algorithms available today.

In 2013, Abdulmohsen Mutairi et al. [1] Proposed Delay Analysis of OFDMA-Aloha. Author provides Aloha and OFDMA-Aloha under the same total bandwidth and load conditions. They derived the precise sharing of the packet access delay of OFDMA-Aloha in the saturated case.

The advantage of that scheme is, using many M additional states representing each stage of the fast retry mode. When a collision occurs in the first time, the retry counter is incremented to m=1, and the packet moves to state S1 When a second collision occurs in the following slot, the packet moves to state S2, continuing this way until the maximum retries limit m = M is reached in state SM. If a collision occurs in state SM, the user gives up retrying and falls back into the backoff state Sbk and resets m = 0. Therefore, the delay seen by the packet is the total time spent in the transient process which is the sum of the time spent in the backoff state and all fast retries states. To find the average time spent in the transient backoff state, Tbk, they could find the transfer function from the input state Sr to state Sbk to obtain the Probability Generating Function.

The disadvantage of that paper, when the network is lightly loaded, OFDMA-Aloha enjoys smaller packet delay, but not for long as it saturates faster than the single channel Aloha.

In 2011, Chong Han et al. [2] Proposed A Novel Distributed Asynchronous Multi-Channel MAC Scheme for Large-Scale Vehicular Ad Hoc Networks.

A fresh spread TDMA based asynchronous multichannel MAC scheme, namely Asynchronous Multi-Channel MAC with a distributed TDMA mechanism (AMCMAC-D) is proposed in that paper. This scheme supports multiple transmissions simultaneously on different service channels and improves the system performance in large-scale networks. However, there has been no all-inclusive performance comparison study to indicate under what conditions the multiple-channel scheme is preferable over the single-channel scheme.

In 2010, Vandhana Gupta et al. [3] Proposed Analytical modeling of bidirectional multi-channel IEEE 802.11 MAC protocols. In that paper, they presented an analytical framework for evaluating multi-channel MAC protocols using M/G/1 queue. To model the dynamics of the protocol and to obtain the performance measures, they applied SRN modeling technique that is an extension of stochastic Petri nets (SPN).

In 2009, Hojoong Kwon et al. [4] Proposed Generalized CSMA/CA for OFDMA Systems: Protocol Design, Throughput Analysis, and Implementation Issues. In that work, author presented a multi-channel carrier sense multiple access with collision avoidance (CSMA/CA) protocol for orthogonal frequency division multiple access (OFDMA) Systems. The CSMA/CA system in conventional single-channel operation has the advantage of not requiring the signaling for bandwidth request and allocation over the scheduled access system but it sacrifices system efficiency significantly. They overcome the system efficiency limitation by exploiting the OFDMA system features that multiple stations can transmit all together on dissimilar sub-channels, and the stations can acquire the channel in order of all the sub-channels at each time instant. The OFDMA-based multi-channel CSMA/CA protocol is considered to enable the stations to contend with each other for channel access both in time and frequency domains through a two-dimensional back off scheme. The protocol takes a comprehensive form of the predictable single-channel CSMA/CA protocol: It allows segmenting the channel bandwidth into multiple narrow-band random access channels and adjusting the transmission probability according to the multi-channel movement in a flexible manner. For throughput analysis, they develop a multi-channel p-persistent CSMA protocol that can follow the multi-channel CSMA/CA protocol and then analyze its saturated throughput. The simulation and analysis results reveal that the proposed system performs far better than the single-channel CSMA/CA system while using the same total bandwidth and even close to the programmed access system. Further, they examine how inflexible time synchronization is necessary among the constituent stations in implementing of the OFDMA-based multi-channel CSMA/CA system.

In 2010 Guner D. Celik et al. [6] Proposed MAC for Network with Multipack Reception Capability and Spatially Distributed Nodes. They show that in networks with spatially distributed nodes, reusing back off mechanism originally designed for narrow-band systems (e.g., CSMA/CA) is inefficient. They showed that their alternative back off mechanism can improved both overall throughput and fairness.

In 2009 Jing Deng et al. [7] Presented Can Multiple Sub channels improve the Delay Performance of RTS/CTS-Based MAC Schemes. They analyzed the delay performance of RTS/CTS-based multi-channel MAC schemes for wireless networks. These schemes typically make use of numerous data Sub channels for data transmission and one control sub-channel to send RTS/CTS discourse for channel reservation. Through theoretical analysis and simulations, they exposed that, in fully-associated networks, such multi-channel MAC schemes suffer longer delays than the corresponding single channel MAC scheme, which puts the RTS/CTS discourse on the same channel as data packet transmissions. That conclusion holds even when data packets have special priorities and superior priority traffic is sent further on of lower main concern traffic.

In 2008 Yihan Li et al. [8] proposed On the Performance of Distributed polling Service-based Medium Access Control. They studied the problem of improving the efficiency of MAC protocols. They first analyze the popular p-Persistent CSMA scheme and shown that it does not achieve 100% throughput. Over the years, many MAC protocols have been proposed for wireless networks, such as ALOHA, Slotted ALOHA, carrier sense multiple access (CSMA) (with several versions), and CSMA with collision avoidance (CSMA/CA). The CSMA/CA-like IEEE 802.11 MAC has become the most popular protocol for single or multi-hop wireless networks. However, the IEEE 802.11 MAC has a extensive control overhead. In that paper, they studied the problem of improving the efficiency of wireless MAC protocols. For simplicity, they first consider a single-hop ad hoc network, where all nodes can hear and directly communicate with each other, and then discuss how to extend their work to multi-hop wireless networks. They examined the reservation-based p-Persistent CSMA scheme (called p-Persistent CSMA in that paper), which uses RTS/CTS for contention resolution and p-Persistent carrier sensing when sending RTS frames. That scheme differs from the standard IEEE 802.11 protocol only in the selection of the back off interval. Instead of the binary exponential back off used in the standard, a back off interval sampled from an arithmetical sharing with limitation p is used.

In 2009 Raymond Yim et al. [10] Proposed Fast Multiple Access Selection Through Variable Power Transmissions. In that paper, they introduced an awfully fast contention-based multiple access algorithm that selects the best node and requires only local information of the priorities of the nodes. The algorithm, which they call inconsistent Power Multiple Access Selection (VP-MAS), uses the local channel state information from the accessing nodes to the receiver, and maps the priorities onto the receive power. It is based on a key result that exposed that mapping onto a set of disconnected receive power levels is optimal, when the power levels are chosen to make use of packet capture that essentially occurs in a wireless physical layer. The VP-MAS algorithm adjusts the expected number of users that contend in each step and their respective transmission powers, depending on whether previous transmission attempts resulted in capture, idle channel, or collision. They also showed how reliable information regarding the total received power at the receiver can be used to improve the algorithm by enhancing the response mechanism.

In 2011 Manal Al-bzoor et al. [12] proposed Wimax Basic from PHY Layer to Scheduling and Multicasting Approaches. They addressed and compared different scheduling approaches defined for WiMAX PMP and Mesh modes. They also studied the multicasting schemas in PMP modes which is based on the Multicast Broadcast service already defined in MAC layer for PMP mode, and showed how multicasting schemas in Mesh mode follows the multicasting schema used for wireless mesh networks defined for IEEE 802.11. It is worth to mention that the current working standard approved in late 2009 is the 802.16 that supports MMR mode of operation, and withdraw the Mesh Mode.

In 2013 S.SYED et al. [13] Proposed FPGA Implementation of 3GPP-LTE physical downlink control channels using diversity techniques. In that

paper, an optimized architecture for downlink for all control channels with transmitter and receiver which include scrambling, modulation, layer mapping, precoding and mapping to resource elements. The 3GPP (Third Generation Partnership Project) has been motivated to work on the Long-Term Evolution (LTE) standard, due to heavy usage of mobile data with many new applications like multimedia online gaming, mobile TV, streaming of video contents etc.
Now, LTE is a new wireless standard in mobile network technology.

In 2006 Yunghsiang S. Han et al. [11] Proposed Analyzing Multi-Channel Medium Access Control Schemes with ALOHA Reservation in that work they presented analyze and evaluate the maximum achievable throughput of a class of generic multi-channel MAC schemes that are based on the RTS/CTS (Ready-To-Send/Clear-To-Send) conversation and on ALOHA contention resolution. They are calculated this multi-channel MAC schemes fewer than two split-channel scenarios: the predetermined-total-bandwidth scenario and the preset-channel-bandwidth scenario. In broad-spectrum terms, they investigate there a set of generic multichannel MAC schemes, which are unspecified to be based on the RTS/CTS discourse. Even though the proposed analysis is based on pure ALOHA contention resolution technique, the approach that they taken in that paper can also be used with other contention resolution techniques, when average time of contention period is known or could be obtained. The message and result of that paper is while using multiple sub-channels instead of a single shared channel may solve certain problems, such as eliminate and decrease collisions between data packets, overall it may not precede the throughput performance of a MAC scheme.

In 2006 Richard T.B. Ma et al. [5] Proposed Modeling and Analysis of Generalized Slotted-Aloha MAC Protocols in Cooperative, Competitive and Adversarial Environments. In that Paper They evaluate the channel utilization and fairness of these types of protocols for a variety of node objectives, as well as maximizing comprehensive throughput of the channel, each node tightfistedly maximizing its individual throughput, and aggressor nodes that attempt to jam the channel. In that work, they consider a generalization of the slotted-Aloha protocol. Like slotted-Aloha, the judgment to transmit within a slot has a random component. However, untraditional slotted-Aloha, the user continues transmission in succeeding slots until a succeeding collision. In their comprehensive version, the user may come to an end transmitting with some fixed (non-zero) possibility. They representation a system of users implementing this generalized protocol with tunable parameters via Markov Models that allow to measure the rate at which nodes attempt to transmit packets (cost), and their rates of success (throughput).

3. Problem Description in MAC Sub Layer Algorithm

The 802.11 MAC sub layer protocol is quite different from that of Ethernet due to the inherent complexity of the wireless environment compared to that of a wired system. With Ethernet, a station just waits until are ether goes silent and starts transmitting. If it does not receive a noise burst back within the first 64 bytes, the frame has almost assuredly been delivered correctly. With wireless, this situation does not hold. In the seventies, the ALOHA system was proposed by Norman Abramson as an effective solution to provide for wireless access to computer systems. The ALOHA-net at the University of Hawaii employed fixed transmitters at islands located at ranges of several tens of kilometers. The main advantage of the ALOHA random access scheme was simplicity. Terminals can transmit their data regardless of the activity of other terminals. If a message is successful the base station sends an acknowledgement over a feedback channel. If the terminal does not receive an acknowledgement, the terminal retransmits the message after waiting a random time. The delay is mainly determined by the probability that a packet is not received (because of interference from another transmission, called a "collision") and the average value of the random waiting time before a retransmission is made.

The original version of ALOHA used two distinct frequencies in a hub/star configuration, with the hub machine broadcasting packets to everyone on the "outbound" channel, and the various client machines sending data packets to the hub on the "inbound" channel. If data was received correctly at the hub, a short acknowledgment packet was sent to the client; if an acknowledgment was not received by a client machine after a short wait time, it would automatically retransmit the data packet after waiting a randomly selected time interval. This acknowledgment mechanism was used to detect and correct for "collisions" created when two client machines both attempted to send a packet at the same time. ALOHA primary importance was its use of a shared medium for client transmissions. Unlike the ARPANET where each node could only talk directly to a node at the other end of a wire or satellite circuit, in ALOHA all client nodes communicated with the hub on the same frequency. This meant that some sort of mechanism was needed to control who could talk at what time.

Hidden Station Problem

The hidden station problem occurs when a node initiates a transmission which causes collision at the receiver of an ongoing exchange. To start with, there is the hidden station problem mentioned earlier and illustrated again. Since not all station are within radio range of each other, transmission going on in one part of a cell may not be received elsewhere in the same cell.

Exposed Station Problem

The exposed station problem occurs when a node reserves the channel for a particular exchange, precluding other exchanges which cause no collision at the receiver from simultaneously occurring. In addition, there is the inverse problem the exposed station problem. Most radios are half duplex, meaning that they cannot transmit and listen for noise bursts at the same time on a single frequency. As a result of these problems, 802.11 do not use CSMA/CD, as Ethernet does. The exposed station problem unnecessarily reduces the overall network throughput.

Collision Resolution

Presently studies exposed that, for an infinite population of users and under certain channel conditions, the ALOHA system is unstable. Packets lost in a collision are retransmitted, but the retransmission again experiences a collision. This may set off an avalanche of retransmission attempts. Almost surely, the "backlog", i.e., the number of previously unsuccessful packets that need to be retransmitted, grows beyond any finite bound. One method to mitigate instability is to dynamically adapt the random waiting times of all terminals if the base station notices that many collisions occur. Although in random multiple access the collision of packets results in stumpy throughput and energy excess which makes it offensive for many applications, random access in an indispensable approach in wireless networks due to its effortlessness of implementation and low overhead. ALOHA is a widely studied and deployed medium access control (MAC) protocol: almost all deployed cellular systems use ALOHA (or one of its variants) as a mean to request network access for mobile users; ALOHA is commonly used in the control channel of ad hoc wireless networks [1] [5] and [16]. Furthermore, ALOHA is used as a multiple access protocol in local wireless communications [11].

The ALOHA concept is very commonly used in modern wireless communication systems. The call set-up procedure of almost any (analog or digital) cellular telephone system uses some kind of ALOHA random access. But the performance differs from what one would expect in a wire line network.

In a radio channel, packets may be lost because of signal fading even if no contending other signal is present. On the other hand, packets may be received successfully despite interference from competing terminals. This is called `receiver capture'. This effect has a significant influence on the throughput. Optimum frequency reuses for ALOHA Random Access a network differs from frequency reuse for telephony, because the performance criteria differ (throughput / delay versus outage probability, respectively). The best reuse pattern for an ALOHA system is to use the same frequency in all cells.

A problem that occurs naturally in Wireless Networks due to their design is contention and congestion. Contention will occur anytime multiple nodes try to gain channel access to the same forwarder. This happens very frequently, especially when an event is sensed by multiple nodes, which leads to a type of contention that is specifically found in WLANs called spatially correlated contention. Contention also happens quite frequently in WLANs because a WLAN has a traffic pattern. All of the events that are sensed in a network have to be sent to one or more base stations. This traffic pattern causes the nodes closer to the base stations to have to carry a heavier traffic load, which in turn makes the areas surrounding the base stations more congested. Due to the possibility of contention and congestion occurring in all WLANs, many methods have been proposed to detect and control contention and congestion or to try and avoid it.

4. Conclusions

We present a review work of Performance Analysis of Random Access Channel in Wireless Communication Network. In our work, we will study and analyze the theoretical and mathematical model of random access channel using 802.11 MAC protocol and varies standard of 802.11 PHY layer protocol. We will study the possible use of the IEEE 802.11 standards.

5. Future Work

All nodes will operate in the same channel and transmit under a different data rate R. Nodes are equipped with identical half-duplex radios and Omni-directional antennas. We assume nodes will be static and dynamic mode based on a random distribution. The channel access protocols will 802.11. That is, the time axis is not divided into identical synchronized time slots whose duration is assumed to be equal to the transmission time of a packet (which is assumed to be not fixed) plus some overhead duration that includes the maximum propagation delay. Each user can transmit its packet at any time. It is assumed that all nodes always have packets waiting for being transmitted (i.e., heavy traffic load). Conventionally, a newly arrived packet is transmitted in the first slot after its arrival; packets which are not received successfully are buffered and retransmitted after a random delay.

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